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Capacity and Incentive Factors Affecting Individual Scientist's Productivity:

A Comparative and Multilevel Analysis of Nigeria and Ghana Agricultural Research Systems

Catherine Ragasa

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Abstract

This paper analyzes incentive and capacity factors that explain variations in research productivity among 344 agricultural scientists in Nigeria and 237 agricultural scientists in Ghana using multilevel analysis. Education level, years of experience, research linkages, and perceived adequacy of resources and management plans are consistently significant capacity factors in explaining productivity. Reported job satisfaction and reported staff's happiness or satisfaction on organizational climate are statistically significant incentive factors.

Keywords: organizational culture, multilevel analysis, poisson, productivity, research, motivation, Ghana, Nigeria

JEL Code: Q16, L32, D23

1. Introduction

Improvement of agricultural productivity is crucial for food security and poverty reduction (World Bank 2007). Crop yields in many developing countries, especially in sub-Saharan Africa, remain a small fraction of what the rest of the world achieves, for example, maize and rice yields are less than 30 percent of average yields in the world (You and Johnson 2008). Both technical and institutional innovations in production, marketing, and policy processes are important to close the yield gap and achieve greater agricultural productivity. Agricultural researchers and their organizations play a vital role as innovators and partners of other key actors within the innovation systems. Despite various attempts by the development partners and other international organizations to strengthen the capacity of researchers and their organizations in many developing countries, various studies find that their productivity and impact remain low (Eicher 2001, 2004; IAC 2004; Clark 2005). This paper aims to provide a better understanding of factors contributing to limited productivity and impact of agricultural researchers and research organizations.

In other sectors, various studies have analyzed the factors affecting researcher's outputs, productivity, and efficiency (see Gulbrandsen and Smeby 2005; Gonzalez-Brambila and Veloso 2007; Manjarres-Henriquez et al. 2009; Abramo et al. 2009; Ponomariov and Boardman 2010; Costas, van Leeuwen, and Bordons 2010; and Kelchtermans and Veugelers 2011 for more recent studies). Commonly significant individual characteristics include age, square of age, gender, education, discipline, experience, square of experience, position or job classification, linkages and affiliations, and reputation. Female researchers tend to publish less compared to male researchers (Gonzalez-Brambila and Veloso 2007; Turner and Mairesse 2003; Xie and Shauman 1998; Long 1992; Cole and Zuckerman 1984). Only Ponomariov and Boardman (2010) find that gender is not significant in determining the research output. Gonzalez-Brambila and Veloso (2007) find a quadratic relationship between age and the number of publications of a researcher; while Costas and van Leeuwen (2010) shows that top-publishing scientists in the Spanish National Research Council are the youngest within each professional category. Gonzalez-Brambila and Veloso (2007) find that reputation (measured in terms of 10-year stock of publication and citations) has some impact on level of research output. Gulbrandsen and Smeby (2005) found that size, structure, and source of funding received by researchers are significant factors in explaining researchers' outputs.

Limited studies include organizational characteristics in analyzing individual staff productivity or performance. Funding received by organization appears to be significant (see Gulbrandsen and Smeby 2005). Manjarres-Henriquez et al. (2009), in their study of researchers in two universities, find that the dummy for universities is not significant. Gonzalez-Brambila and Veloso (2007) use three different break points associated with three different cohorts (namely the early-educated group of researchers, the middle years, and the latest educated) and find no significant difference between the first and the latest educated and that the second cohort is slightly more productive than the latest educated. Bonaccorsi and Daraio (2003) perform an efficiency analysis using biometrics data as output and find that location and geographical agglomeration to be significant in determining research outputs in French institutes but not in Italian institutes. Lorenz and Lundvall (2010) show that creative employees are over-presented in business services and social and community services than in manufacturing, construction, and utilities. The authors show that institutional and national context have a significant direct impact on the individual creativity at work across 27 European research organizations.

Another set of literature looks at organizational culture (OC) that affects employee satisfaction (Gregory et al. 2009); staff turnover (Stone et al. 2007); motivation of staff and managers (Moynihan and Pandey 2007); extent of knowledge sharing (Willem and Buelens 2007); organizational performance and effectiveness (Ogbonna and Harris 2000); and the diversity and nature of use of performance measure systems (Henri 2006). Various authors describe and measure organizational culture or climate using slightly different concept and definitions. Marshall and McClean (1988) define it as "the collection of

traditions, values, policies, beliefs, and attitudes that constitute a pervasive context for everything we do and think in an organization.” Quinn and Rohrbaugh (1983) develop the commonly cited “Competing Values Model,” which incorporates two sets of competing values: (1) the control versus flexibility dilemma, which refers to preferences about structure, stability, and change; and (2) the people versus organization dilemma, which refers to differences in organizational focus. Combination of two sets of competing values gives rise to four different dominant culture types: (1) group, (2) development, (3) rational and (4) hierarchical cultures (Henri 2006; Gregory et al. 2009). A balanced culture occurs where there is no dominant culture type. This balanced culture has been well favored by various authors (Quinn 1988; Yeung et al. 1991; Quinn and Spreitzer 1991; Ramanujam and Rousseau (2006); Gregory et al. 2009).

Authors such as Gregory et al. (2009), Stone et al. (2007), Moynihan and Pandey (2007), Willem and Buelens (2007), Ogbonna and Harris (2000), and Henri (2006) use a wider classification of OC combining measures of transparency, fairness, political autonomy, coherence, mobility, openness, responsiveness, flexibility, participatory leadership, adequacy of resources, and employee morale or satisfaction. Willem and Buelens (2007) use coordination mechanisms (i.e., formal systems, lateral coordination, and informal coordination) and contextual organizational variables (i.e., power games, trust, and identification). Biggs and Smith (2003) use two criteria — degree of group cohesion and degree of institutionalized rules and procedures as criteria— to evaluate OC. Based on these criteria, the authors classify OC into four categories namely: (1) hierarchical (high in group cohesiveness and high in predetermined rules); (2) fatalist (low in group cohesiveness and high in predetermined rules); (3) individualist (low in group cohesiveness and low in predetermined rules; and (4) egalitarian (high in group cohesiveness and low in predetermined rules). However, Biggs and Smith (2003) emphasize that these classifications are not to compare model or justify preferred models nor neatly put organizations into these boxes since organizations, projects, or programs can contain multiple organizational culture.

Despite some differences, a common feature of studies on OC is the use of individual’s perceptions on OC as a proxy to measure OC and authors find this perception variable significant. Moreover, these individual perceptions are treated as an organizational- or institutional-level variable. While individual perception can be an indicator for organizational or institutional context, the dataset used in this paper suggests that individual perception vary within organizations and thus cannot be interpreted as “organizational- or institutional-level variable.” This suggests that perception variable can be best treated as individual-level explanatory variable rather than a variable that represents organizational or institutional context. On the other hand, relative values assigned for control versus flexibility as described by Henri (2006) and Gregory et al. (2009) are measures of organizational culture types but can depend on the nature of the leader of the organization and influenced by individual researchers who can demand or induce changes in the organizational culture type overtime. Because of these, both perception on OC as an individual-level factor and type of organizational culture type as an organizational-level factor may be endogenous to the research output model.

This paper aims to provide a better understanding of the systematic relationship between organizational characteristics and perception on organizational culture and that of individual researcher’s productivity. This paper contributes to existing literature and fills some of the research gaps identified above through the following ways: (1) it employs a multi-level analysis that differentiates individual versus organization-level factors; (2) it differentiates proxies for measures of capacity versus proxies for measures of motivation as explanatory variables; (3) it goes beyond usual measure of research output to include some proxies for research quality such as the presence of external collaboration, extent of dissemination of publications and knowledge of adoption level of technologies produced; (4) it uses individual’s perception on organizational culture as individual-level explanatory variable rather than a variable that represents organizational- or institutional-level variable, often used in the literature; and (5) it formally tests and models organizational culture type and presence of organizational management

practices and systems as endogenous to the individual research output model. A multilevel analysis applied to survey data on Nigerian and Ghanaian agricultural researchers suggests that organizational characteristics systematically explain variance in individual productivity after adjusting for the effects of differences in individual characteristics. This paper focuses on the differences and similarities between Nigeria and Ghana case countries and does not provide detailed description of the data or the analyses of individual country's regression models. This paper is intended to be concise and concentrates on the key comparisons between Nigeria and Ghana to provide implications and suggestions to the ongoing reform processes in these two countries' agricultural research systems. For specific details, earlier studies utilizing the same dataset can be referred to including Ragasa et al. (2010) on Nigeria research systems and Ragasa, Abdullahi and Essegbey (2011) on the research performance measures of these two countries.

Case studies of Nigeria and Ghana

The size and importance of agriculture sector are similar in Ghana and Nigeria, but indicators of the performance of the agricultural sector and development indicators in general are much more favorable in Ghana than in Nigeria. Table 1 summarizes the socio-economic and agricultural sector statistics of these two countries.

The Nigeria national agricultural research system (NARS) is the largest and most complex national agricultural research system in Sub-Saharan Africa. Nigeria represents a large, complex and diverse system operating in a historical context of governance, institutional and funding instability, which severely impacts agricultural research. Ghana represents a relatively small-system case operating within a more stable governance environment but its NARS is hampered by serious financial, human and physical capacity constraints.

Table 1: Summary of Socioeconomic statistics and description of the agricultural research systems in Nigeria and Ghana

Indicators	Nigeria	Ghana
<i>Social and economic indicators</i>		
Population (2010)	158,258,917	24,332,755
Poverty headcount ratio at national poverty line (% of population) (2009)*	64.4%	35.5%
GNI per capita US\$ (2010)	1,180	1,240
Life Expectancy in years (2009)	48	57
Literacy Rate (% of population) (2009)	61	67
GDP growth rate* (2009)	2.9%	4.5%
Malnutrition rates* (2009)	28.7%	13.9%
Share of agriculture in GDP	33% (2006-2007)	31% (2006-2009)
Percentage of agricultural investment to total public expenditure* (2009)	4.5%	5.8%
Ratio of agricultural investments to AgGDP* (2009)	<5%	<2%
AgGDP growth rate* (2009)	-0.3% (2009)	4.5% (2009)
<i>Agricultural research system**</i>		
Number of technology produced (1997-2008)	207	106
Ratio of technology produced (1998-2008) to total number of researchers [FTE] (1990-2005) (Technology/researcher)	6	4
Number of researchers ([FTE] (2008)	2062	537
Number of researchers ([FTE] (1990-2005)	1,250	390
Number of rural population per FTE researcher	39,300	21,800
Agricultural research expenditure (million PPP	392	95

dollars) [2008]		
Agricultural research expenditure (million PPP dollars) [1990-2005]	170	38
Agricultural research expenditure (% of AgGDP) (2008)	0.40%	0.53%

Source: World Bank - <http://data.worldbank.org/country/> (accessed 3rd Sept. 2011) if not specified; * Omilola and Lambert (2010). ** Ragasa, Abdullahi and Essegbey (2011).

Both countries have undertaken a series of reforms and restructuring in the NARS. Some have been similar types of reforms (e.g., decentralization and establishment of linkage committees called Research-Extension-Farmers-Input-Suppliers Linkage Systems (REFILS) and Research-Extension-Linkages Committee (RELCs) in Nigeria and Ghana respectively), but both countries have showed limited effectiveness and continued weaknesses. The two countries' agricultural research systems have been studied individually (Beintema and Ayoola 2004; Flaherty et al. 2010; Flaherty, Essegbey and Asare 2010), but in-depth comparative analyses have not been done. Findings in this paper have put forth insightful comparisons and some lessons that these two countries can learn from each other.

The rest of the paper is structured to present the conceptual framework, followed by a short description of the data sources, and data collection methods. The findings and key comparison of the two countries are presented in the "Results" and "Discussion and Policy Implications" sections. This paper ends with the conclusions and key messages for Nigeria, Ghana and wider research and development community.

2. Data and Methods

The data and information used in this paper were collected using multiple sources. A face-to-face survey using computer-assisted personal interview mobile device was jointly conducted by IFPRI and the Agricultural Research Council of Nigeria (ARCN) in Nigeria between May and July 2010 and a similar survey was jointly conducted by IFPRI and the Science and Technology Policy Research Institute (STEPRI) in Ghana between May and July 2011. This survey was complemented by key informants' interviews and review of relevant literature.

In Nigeria, a total of 47 relevant public sector organizations involved in agricultural research were interviewed by the IFPRI-ARCEN-STEPRI research teams consisting of all 15 agricultural research institutes under ARCN, all 11 federal colleges of agriculture, and 21 faculties of agriculture and veterinary medicine in federal universities out of a total of 48 faculties in 2010 records of ARCN (based on willingness of organizations to participate and respond to the survey). In Ghana, a total of 16 public sector organizations involved in agricultural research were interviewed involving all 10 agriculture-related research institutes under CSIR; 1 non-CSIR institute, Cocoa Research Institute of Ghana, out of 3 relevant research center that is not under CSIR; and 6 faculties of agriculture in public universities out of 15 identified by STEPRI and ASTI (Flaherty et al. 2010) (the sample organizations that are non-CSIR and universities were based on willingness of organizations to participate and respond to the survey).

Face-to-face survey of 3-20 randomly selected staff per organization were then conducted by the IFPRI-ARCEN-STEPRI teams. The actual sample was based on the total number of research staff: in Nigeria (26-140 research staff in research institutes and 5-214 staff conducting research in universities) and Ghana (10-77 research staff in research institutes and 5-29 staff working on research in universities). In Nigeria, a total of 344 sample researchers were interviewed out of a total more than 3,000 relevant staff; while in Ghana, out of a total of 706 total researchers, 237 individual researchers were randomly selected and interviewed.

This paper is interested in identifying factors that are associated with higher levels of performance among individual researchers. There are three sets of indicators of research performance: (1) literature on conventional research outputs, including publication, technology and training (such as Lantican et al. 2002); (2) literature on public sector motivation and performance and organizational theory (for example, Manning et al. 2002; World Bank 2001); and (3) literature on agricultural innovation systems indicators (based on Hall et al. 2000, 2001; Hall, Mytleka, and Oyeyinka 2006; World Bank 2006; Spielman and Birner 2008; CTA 2009). Most of the studies that looked at individual scientist's outputs or productivity are in developed country context and the commonly used indicator is the number of publications using available bibliometric data. Due to limited availability of international databases of locally produced journals and books in many developing countries, this paper relied to self-reported number of publications. The scope of publications used in this paper is limited to journal articles, books and book chapters published in the last 3 years. Following Lantican's et al. (2002) study, the number of technologies that a researcher helped in producing is also included as one of the measures of research productivity. These technologies include biological technologies, such as new varieties or breed; chemical or mechanical technologies; and improved production, marketing, and management practices in the last 5 years. Following the studies on agricultural innovation systems, indicators of linkages and use of the research outputs are also included as a measure of the quality of research outputs. Two dependent variables are included: presence of international collaborators and national collaborators in developing technologies and producing publications. An indicator of the knowledge and awareness of any evaluation or adoption rate of technologies produced is also included. A measure of the extent of dissemination of publications produced is also added.

The factors that are hypothesized as important in explaining variations in individual research productivity are visually structured and presented in figure 1. Both individual characteristics and organizational-level factors are hypothesized as significant factors in explaining variation in individual productivity. The list of individual-level and organizational-level covariates and their descriptions are given tables 3 and 4. Education level, years of work experience, age, and gender of researcher have been proven to be statistically significant in most past studies on research productivity (Costas and van Leeuwen 2010; Gonzalez-Brambila and Veloso 2007; Gonzalez-Brambila and Veloso 2007; Turner and Mairesse 2003; Xie and Shauman 1998; Long 1992; Cole and Zuckerman 1984). The time allocated to research is also significant in a number of studies. Following public sector motivation and performance literature and organizational theory, this paper includes a measure of individual researcher's perception on organizational practices and work environment. It is hypothesized that perception of a more conducive more environment is positively related to both quantity and quality of research outputs by individual researchers.

There are limited studies at look at organizational factors that explain individual-level research productivity. In this paper, we utilize a multi-level analysis following a conceptual framework presented in Figure 1. Multi-level modeling allows to model processes at multiple levels of the population hierarchy. By simultaneously modeling at multiple levels it is possible to determine where and how effects are occurring (Lorenz and Lundvall 2010; Rasbash et al. 2005; Goldstein 2003). Multilevel modeling also responds to the criticism often made of single-level models that too much emphasis is placed on individual's characteristics and neglect the social, institutional, or organizational context (Lorenz and Lundvall 2010; Rasbash et al. 2005; Goldstein 2003). Failure to take into account the hierarchically structured nature of the data may lead to serious technical problems, with standard errors of the regression coefficients being underestimated.

The organizational level factors used in the paper include various composite indices on the adequacy of human resources, physical resources, communication and information system, organizational management systems and policies, organizational linkages, and organizational culture type. Twenty indicators of organizational culture (OC) based on the perception of individual scientists are expressed as

a composite index from factor analysis, OCINDEX. Six indicators of adequacy of communication and information systems based on leader's satisfaction level are expressed as a composite index from factor analysis, COMINDEX. Three indicators of adequacy of physical resources based on leader's satisfaction level are expressed as a composite index from factor analysis, PHYINDEX. Other indicators expressed in composite indices are the 8 indicators of formal linkages with other organizations, LINKINDEX and 6 indicators of organizational management plan or M&E system, PLANINDEX. Organizational culture type (group, developmental, hierarchical and rational culture types and the values given to control versus flexibility as the dominant organizational culture type) as defined and used in Henri (2006) and Gregory et al. (2009) studies are employed in the Ghana part in this paper, CONTROL.

We hypothesize that these variables are endogenous to the individual research productivity model. This means that it may be true that while organizational practices and culture type can induce more productivity among individual researchers, productive individual researchers may also be to demand or induce organizations to provide these systems and changes toward a greater more conducive more environment. Instrumental variables are used including leader's characteristics, year of establishment of organization, leadership style, and geographical location which may directly affect organizational practices and culture type but not directly affect individual productivity. Regression analyses suggest that geographical location and leadership characteristics are significant. The predicted values of organization-level factors are used in the second-stage regression analysis explaining variations in individual research productivity (i.e., HUMINDEXHAT, COMINDEXHAT, PHYINDEXHAT, PLANINDEXHAT, LINKINDEXHAT, CONTROLHAT and OCINDEXHAT).

Two sets of questionnaires were used—one questionnaire for organizations, to be answered by organization heads or a designated representative, and another for individual researchers. The questionnaire for organizations included questions on the organization's mission; research management issues and training needs; scientific and technical training needs; the availability of physical and human resources; research outputs; management systems and procedures; partnerships and linkages; accountability and motivations; and funding sources. The average time taken to answer the organization questionnaire was 2.5 hours. The questionnaire for individual researchers covered demographic and individual characteristics; research outputs; workload; linkages; research issues and training needs; motivation and incentives; and perception of the organization's culture. The average time taken to answer the individual questionnaire was 2.5 hours.

Our analysis of research productivity operates at two levels, with individual employees at level-1 being clustered within organization at level-2. Our variables characterizing employees at level-1 are derived from the individual responses to IFPRI-ARCN and IFPRI-STEPRI individual-level survey questionnaire; while our variables characterizing the organizational context at level-2 are derived from the IFPRI-ARCN and IFPRI-STEPRI organization-level survey questionnaire administered with heads or designated representative of organizations, complemented by ASTI dataset.

In a simple two-level model, the linear predictor with random intercept and coefficient for organization j is given as

$$\eta_{ij} = \sum_{l=1}^k x_{ijl}\beta_{lj} + v_{lj} \quad (1)$$

where η_{ij} is the linear predictor; x_{ijl} is the vector of covariates with fixed effects or the standard coefficient β and $\beta = (\beta_{1j}, \beta_{2j}, \dots, \beta_{kj})$ are unknown k -dimensional column vector of coefficients; the subscript i represents the individual scientists (level-1 units), and subscript j represents organizations (level-2 units); and v_{lj} is the random effect (one for each organization). These random effects represent

the influence of organization j on individual i that is not captured by the observed covariates. These are treated as random effects because the sampled organizations represent a population of organizations, and they are assumed to be distributed as $\mathcal{N}(0, \sigma_v^2)$.

In the two-level model with random intercepts and coefficients, both the intercept and the coefficients vary randomly across the level-two units. Both the intercept term and coefficient consist of two terms: a fixed component β_{1j} , which is similar to standard single-level model, and a random effect v_{1j} due to the fact that the level-2 units are treated as a random sample from a population of organizations. For example, the random effect v_{1j} measures the departure of the j -th unit's intercept from the average or summary intercept across all level-2 units predicted by the fixed parameter, β_1 . Similarly, the random effect v_{2j} measures the departure of the j -th organization's slope from the average slope across all level-2 units predicted by the regression coefficient β_2 . Level-2 context variables can be included directly as covariates in order to estimate the direct effect of differences in organizational context variables on the dependent variable. Such direct effects modify the intercept and slopes and reduce the variability in the intercept and slopes across level-2 units. In its simplest form, the level-1 and level-2 fixed effects and random effect of the intercept across sample organizations is given in equation 2 below:

$$\beta_{1j} = \beta_1 + v_{1j} \quad (2)$$

A link function $G(\cdot)$ to convert the expected value μ_{ij} (i.e., $\mu_{ij} = E[y_{ij} | v_j, x_{ij}]$) of the outcome variable y_{ij} to the linear predictor η_{ij} need to be specified based on the nature of the dependent variable and is given as

$$g(\mu_{ij}) = \eta_{ij} \quad (3)$$

Since several measures of research output y_{ijl} are being used with varying structure and nature of the data, we employ different models in this paper. Table 1 presents the measures and descriptive analysis of research outputs while table 2 presents some indicators of the quality and effectiveness of these research outputs. For the number of publication and number of dissemination events for publications, characterized as over dispersed count data variables, this paper uses the generalized poisson regression (GPR).¹ The generalized poisson regression (GPR) model $f(\mu_i, \alpha; y_i)$ is adopted from Famoye and Singh (2006) and is given by

$$f(\mu_{ij}, \alpha; y_{ij}) = \left(\frac{\mu_{ij}}{1 + \alpha \mu_{ij}} \right)^{y_{ij}} \frac{(1 + \alpha y_{ij})^{y_{ij} - 1}}{y_{ij}!} \exp \left[\frac{-\mu_{ij}(1 + \alpha y_{ij})}{1 + \alpha \mu_{ij}} \right] \quad (1)$$

where the mean of y_{ij} is given by $\mu_{ij}(x_{ij}, v_j)$ and the variance of y_{ij} is given by $V(y_{ij} | x_{ij}, v_j) = \mu_{ij}(1 + \alpha \mu_{ij})^2$; and α is the dispersion parameter. When $\alpha = 0$, the probability model in equation (1) reduces to the Poisson regression model and this is a case of equi-dispersion. When $\alpha > 0$, the GPR model in equation 1 represents count data with over-dispersion. When $\alpha < 0$, the GPR model represents count data with under-dispersion. The non-negative function μ_{ij} is modeled via a log link function given as

¹ An alternative is negative binomial regression (NBR) model which assumes that $\sigma^2 > 1$, so that there cannot be underdispersion. Generalized Poisson Regression (GPR) allows for all types of dispersion. GPR has been a good competitor of NBR and in some instances, it may also have some advantages (Famoye and Singh 2006). In the Famoye and Singh (2006) paper, they successfully fitted the ZIGP regression model to all datasets, but in a few cases, the iterative technique to estimate the parameters of ZINB regression model did not converge. Moreover, GPR has an edge over NBR for estimating parameters of the conditional mean (Wooldridge 2002).

$$\eta_{ij} = \log(\mu_{ij}) = \sum_{l=1}^k x_{ijl}\beta_{lj} + v_{lj} \quad (2)$$

The regression coefficient β_l represents the expected change in the log of the mean per unit change in the regressor x_l . In other words increasing x_l by one unit is associated with an increase of β_l in the log of the mean.

For the number of technologies produced ($y_{ijl} = \text{TECHNO}$), count data with excess zeros, this paper uses a zero-inflated generalized poisson (ZIGP) model adopted from Famoye and Singh (2006) and is given by

$$\begin{aligned} P(Y = y_{ij} | v_i, x_{ij}, z_{ij}) &= \varphi_{ij} + (1 - \varphi_{ij}) f(\mu_{ij}, \alpha; 0), \quad y_{ij} = 0 \\ &= (1 - \varphi_{ij}) f(\mu_{ij}, \alpha; 0), \quad y_{ij} > 0 \end{aligned} \quad (3)$$

where $f(\mu_{ij}, \alpha; y_{ij})$, $y_{ij} = 0, 1, 2, \dots$ is the GPR model in equation (1); $0 < \varphi_{ij} < 1$; x_{ij} represents the set of covariates affecting μ_{ij} ; and z_{ij} represents the set of covariates affecting φ_{ij} . The model in equation (3) reduces to the GPR model when $\varphi_{ij} = 0$. For positive values of φ_{ij} , it represents the zero-inflated generalized poisson regression model. In this set up, the non-negative functions μ_{ij} and φ_{ij} are, respectively, modeled via log and logit link functions given as

$$\eta_{ij} = \log(\mu_{ij}) = \sum_{l=1}^k x_{ijl}\beta_{lj} + v_{lj} \quad \text{and} \quad \eta_{ij} = \text{logit}(\varphi_{ij}) = \log\left(\frac{\varphi_{ij}}{1-\varphi_{ij}}\right) = -\tau \sum_{l=1}^k z_{ijl}\beta_{lj} + v_{lj} \quad (4)$$

where v_{ij} and v_{ij} are random intercepts and coefficients of the log link and logit link functions, respectively. The ZIGP regression model with logit link for φ_{ij} and log link for μ_{ij} as defined in equation (4) will be denoted by ZIGP (τ). When $\tau > 0$, the zero state becomes less likely and when $\tau < 0$, excess zeros become more likely.

For the dummy variables representing presence of at least one international or national research collaborator and knowledge and awareness of adoption level of technologies produced ($y_{ijl} = \text{TECHINTL}$, TECHNATL , PUBINTL , PUBNTL , and KNOWADOPT), binary response variables, the paper uses logit regression model with response probability (equation 5) and logit link (equation 6) given as

$$p(x_{ijl}) \equiv P(y_{ij} = 1 | v_{il}; x_{ijl}) = P(y_{ij}^* > 0 | x_{ijl}) = \frac{\exp(\sum_{l=1}^k x_{ijl}\beta_{lj} + v_{lj})}{1 + \exp(\sum_{l=1}^k x_{ijl}\beta_{lj} + v_{lj})} \quad (5)$$

$$\eta_{ij} = \Lambda(\sum_{l=1}^k x_{ijl}\beta_{lj}) = \text{logit}(\pi_{ij}) = \log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \sum_{l=1}^k x_{ijl}\beta_{lj} + v_{lj} \quad (6)$$

where y^* is a latent variable determined by $y^* = \sum_{l=1}^k x_{ijl}\beta_{lj} + e$, $y = 1[y^* > 0]$, e is the disturbance term; π_{ij} is the underlying probability that $y=l$; and Λ is the logit model.

The dependent variables, y_{ijl} , are modeled using covariates that represent individual characteristics, individual perceptions on organizations, and organizational characteristics given in tables 1-4. The types of organizations (research or higher education institute) are controlled in the models. The GLLAMM command in STATA was used in modeling and adaptive quadrature was utilized to perform the integration over random-effects distribution.

3. Results

The results of the various models estimated suggest that both individual characteristics and organizational factors are statistically significant in explaining research productivity of individual staff in sample organizations in Nigeria and Ghana. However, there are major differences in the statistical significance and direction of correlation of these factors between Ghana and Nigeria and depending on the measures of research output quantity and quality used. This section is organized based on key comparisons of Nigeria and Ghana in terms of factors explaining the number of publications; number of technologies; presence of collaborators in producing publication; presence of collaborators in developing technologies; number of dissemination events of publications; and knowledge of evaluation or adoption of technologies produced. Summary tables of results are in Tables 5-8.

3.1. Publication

The random-effect estimates show that there is considerable variance across the 47 organizations in Nigeria and 16 organizations in Ghana in terms of the number of publications produced by individual researchers (tables 5 and 6). Even after controlling for differences in individual characteristics and including specific organizational-level factors, the random-effect intercept remains significant. This signifies a wide variability across organizations in terms of individual researcher's count of publications in the last 3 years. Some of these variabilities can be explained by organizational factors, such as index for resources, organizational and management practices and systems being used by the organizations in both countries. However, these organization-level factors and their direction and level of significance vary between Nigeria and Ghana. In Nigeria, individual researchers in organizations with organizational M&E system, organizational plans and policies in place and in research institutes have reported more publications than those in organizations without these systems, plans and policies and those in higher education institutes. In Ghana, researchers in organizations that reported more adequate human resources, more conducive organization management practices, and control-dominated and hierarchical culture type have reported more publications than those in organizations that reported less adequate human resources, less conducive organization management practices, and more flexible and group culture type. In Ghana, human resources seem to be the a more pressing constraint, while in Nigeria, physical resources availability, organizational M&E system, and organizational management practices and policies seem to be the more pressing issues in its agricultural research systems.

In terms of individual characteristics, it is consistent that education is a highly significant factor in explaining individual productivity in both countries. Length of stay in the organizations (proxy of experience and familiarity in the organization) is also consistently significant. Gender is also significant, but of different signs between Nigeria and Ghana. Female researchers reported more publications in Ghana than male researchers; and it is the opposite in Nigeria.

3.2 Technology

In both Ghana and Nigeria, organizational factors are significant in explaining variations in the number of technologies produced by individual researchers (tables 5 and 6). For Nigeria, index for communication system, physical resources, organizational plans, organizational linkages, and conducive work environment are significant and positively associated with the number of technologies produced. The surprising result in the negative correlation of index for adequacy of human resources to number of technologies produced. This suggests that the adequacy of human resources is less of an issue in Nigeria than in Ghana and this may also suggest some degree of overstaffing or other human resources management issues in Nigeria in relation to improving research outputs and productivity. For Ghana, organization-level index for communication system is significant in explaining the variation in the

number of technologies produced by individual researchers. The random-effect intercept, after controlling for organizational-level factors remain significant, which means that the nature and other characteristics of the sample organizations are important factors in explaining individual productivity.

In terms of individual characteristics, similar to publications produced, the education level of researchers is significant in explaining variations in individual productivity in both Nigeria and Ghana. The number of years after highest educational attainment is significant in Ghana but not in Nigeria, and the direction of effect are opposite between these two countries. The number of years in the organization is significant for both countries but of different direction. More number of years in the current organization is negatively associated with the number of technologies produced by individual researchers in Nigeria and positively associated with technologies produced by individual researchers in Ghana. More time allocated for research is positively associated with technology produced by individual researchers in Nigeria and negatively related to technologies produced by individual researchers in Ghana. In Nigeria, female staff have reported fewer technologies produced than male researchers; while in Ghana, it is the opposite, that is, female researchers produced more than their male counterparts, although it is not statistically significant. The perception on organizational management practices reported by individual researchers is significant for both Nigeria and Ghana in explaining variations in the count of technologies produced.

There is a difference in terms of factors that explain whether researchers produce technology or not and the number of technologies for those who produced at least one technology. For individual characteristics, in Nigeria, only the number of years in the current organization is statistically significant in explaining whether researchers produce technology or not; while education level, gender of researcher and time allocation for research activities are also statistically significant in explaining the count of technologies for those researchers at produced at least technologies. For organizational level factors, in Nigeria, the statistic significance of the index on communication system, physical resources and organizational plans are similar in explaining whether researchers produce technologies or not and the count of technologies produced. The index for human resource availability is statistically significant in explaining whether an individual researcher produces technology or not; while the index for organizational linkages, perception on organization culture, and organization type are statistically significant in explaining the variation in the count of technologies for those who developed at least one technology. These results for Nigeria imply that there are different factors that motivate or enable individual researchers to produce technologies or not and the number of technologies for those that produced at least one technology.

In Ghana, there are no factors, both at individual and organizational level, that systematically explains why researchers would produce technologies or not. For those who produce at least one technology, the factors that are statistically significant are numerous. At the individual level, education level, years after highest education level, square of years after highest education level, years in current organization and time allocation for research are statistically significant in explaining variations in the number of technologies produced. Higher education level is positively associated with the number of technologies produced by individual researchers. There is a quadratic relationship between years of work experience and number of technologies produced by individual researcher. The more years of experience after highest education attainment is positively associated with the number of technologies produced by individual researchers at some point until the relationship starts to go to the opposite direction. More number of years of work in the current organization is associated with higher number of technologies produced by individual researchers. Surprisingly, the number of technologies decreases with more time allocated to research, which is the opposite of what was initially hypothesized. To put in into perspective, the number of publications produced in Ghana is not associated with the time allocated to research, which implies that the lack of time for research compared to other activities may not seem as an issue for Ghana. In Nigeria, it is the opposite: more time allocated for research is statistically significant in explaining both the number of publications and technologies produced by individual researchers.

There are other commonalities between factors affecting the number of publication and technology produced and between Nigeria and Ghana. In Nigeria and Ghana, education level and proxy for experience are consistently significant factor explaining variations in the number of publication and technologies produced. Higher education levels are associated with more publications and technologies produced in Nigeria and Ghana. There is a quadratic relationship between the years of work experience and the number of technologies produced by individual researchers. More number of years after highest education attainment is associated with more publications and technology produced at a certain point until the number of publications and technologies start to decline with experience. The type of organization, that is, research institutes have reported more publications and technologies produced than higher education institutes. In Ghana, there is no significant difference. The number of publications produced in Ghana and technologies produced in both countries is linked to individual perception on conducive organization management practices (except of publications produced in Nigeria).

3.3 Collaboration in publications

Individual factors are associated with international research collaboration in Ghana and Nigeria and national research collaboration in Nigeria (table 7). Education level is consistently significant in explaining the international research collaboration and number of dissemination events by individual researchers in Ghana and Nigeria. However, a surprising result is on the direction of significance in explaining national research collaboration in both countries, that is, the higher the education level, the less likely individual researchers collaborate with other researchers in their publications. There seems to be a substitution of international collaboration from national collaboration as one achieves higher education background in both countries.

More years in the current organization is positively association with international research collaboration by individual agricultural researchers in Ghana. The number of years after highest education level is also significant in explaining national research collaboration by individual agricultural researchers in Nigeria.

Except of a slight significance of index for communication system (explaining national research collaboration), there seems to be no organizational factors that are statistically significant in explaining both national and international research collaboration. It seems that international and national collaboration of researchers in their publications are explained mainly by differences in individual characteristics, especially education level and years of experience, and not on the nature or characteristics of organizations they are in.

3.4 Collaboration in technology development

Only education is significant in explaining variations in technology development collaboration in Nigeria (table 8). Higher education level is positively associated with presence of international collaboration in technology development. No variable (both individual and organizational level factors) is statistically significant in explaining national collaboration in technology development in Nigeria in our models.

For Ghana, there are no individual factors that are statistically significant in explaining both national and international collaboration in technology development, except for time allocated for research. More time for research is positively associated with international collaboration in technology development. In terms of organizational factors, the index for physical resources and index for organizational linkages are significant and positively associated related to national and international collaboration. However, index for communication system is negatively associated with both national and international collaboration.

3.5 Dissemination of publications

Both individual and organizational factors are significant in explaining the number of dissemination events to communicate the findings of research (table 7). Education level is consistently significant in explaining the number of dissemination events of sample agricultural researchers in Nigeria and Ghana. Higher education level is positively associated with more dissemination events. The number of years of experience after highest education attainment is also significant, although the effect is opposite for Nigeria and Ghana. More years in the current organization is positively associated with number of dissemination events in Ghana. Female researchers have less dissemination events for both Nigerian and Ghana (although it is not significant for Nigeria). The time allocated for research is also significant but with opposite direction between Nigeria and Ghana. The more time allotted for research is positively significant with the number of dissemination events in Ghana and negatively significant in Nigeria.

In terms of organizational factors, the index for physical resources and index for linkages are positively significant in Ghana but not significant in Nigeria. Researchers in research institutes have more dissemination events for their publications than higher education institutes in both Nigeria and Ghana.

What is surprising is the direction of correlation of index on individual perception on organizational culture in Nigeria. Perception of less conducive work environment is associated with more dissemination events in Nigeria and this is the opposite of what was initially hypothesized. The direction of correlation for Ghana is consistent with the hypothesis but it is not statistically significant.

3.6 Knowledge of evaluation and adoption

More years in the current organization is positively associated with individual researcher's greater reported knowledge and awareness of adoption of technology produced in Nigeria (table 8). Researchers in research institutes have more knowledge and awareness of adoption or evaluation than higher education institutes. Individual researcher's perception of organizational culture is significant in explaining knowledge on adoption or evaluation of technologies produced. More conducive work environment reported is associated with more knowledge on adoption and evaluation of technologies produced for both Nigeria and Ghana (although not statistically significant for Nigeria).

4. Discussions and Policy Implications

There is huge variability in the research outputs, productivity, organizational linkages, and extent of dissemination and knowledge of adoption of technologies produced among individual researchers and organizations involved in agricultural research in Nigeria and Ghana. Both individual and organizational characteristics are significant in explaining variations in publications and technologies produced. Education level is strongly and positively significant in explaining variations in the number of publications and technologies produced, external research collaboration, and the number of dissemination events for these publications. This implies that while interventions are needed to improve education level and skills development of staff, interventions to improve the workings of organizations will also be needed.

In terms of individual characteristics, it is consistent that education is highly significant factor. Length of stay in the organizations (proxy of experience and familiarity in the organization) is also consistently significant. Gender is also significant, but of different signs between Nigeria and Ghana. Female researchers are less likely to have more number of publications and more technologies produced than male researchers in Nigeria but it is the opposite in Ghana. Female researchers are more likely to have more publications and technologies produced but they are likely to have less dissemination events than their male counterparts in Ghana.

There are mixed results in terms of the effect of time allocation for research between Nigeria and Ghana and among the dependent variable being explained. More time allocated for research seems to be positively associated with the number of publications and technologies in Nigeria and negatively related to number of technologies in Ghana. It is positively correlated with international collaboration in technology development and number of dissemination events in Ghana but negatively correlated with national research collaboration and number of dissemination events in Nigeria.

There is also mixed results in terms of the effect of years after highest educational attainment between Nigeria and Ghana and among the various dependent variables being explained. More number of years after highest educational attainment is positively associated with the number of publication and technologies and dissemination events in Ghana but negatively associated with national research collaboration and number of dissemination events in Nigeria.

The pressing organizational constraints may be different from organization to organization and from country to country. For Ghana, index for human resources availability seem to be a significant factor in the number of publications produced. In terms of the number of technologies produced and external collaboration, other organizational factors including indices for communication system, linkages, physical resources, and the type of organizational culture become significant for Ghana. In Nigeria, almost all indices of organizational management practices, systems and resources are statistically significant across different models. These imply the need for differentiated priorities and strategies needed in the reform processes in these countries. In both Nigeria and Ghana, leadership style and characteristics of the organization head are significant in explaining variations in organizational practices and type of organizational culture.

For Nigeria, results suggest the need to strengthen and invest in organizations if the Nigerian government aims to increase the research productivity of its agricultural research system. In 2010, only 30 organizations have M&E plans and a majority does not have strategic plan and IPR policy. In the context of Nigeria, in terms of prioritization, human resources development seem to be the least of the problems compared to the serious deficiencies in laboratory, research facilities, and infrastructure and in poor implementation of management systems and organizational procedures. Measures of availability and adequacy of physical resources and organizational management systems seem to be more consistently significant than measures of availability of human resources in Nigeria case. Investing in physical resources and better enforcement organizational management systems seem to be the more important factors that would increase the likelihood of increasing research productivity.

For Ghana, the Council for Scientific and Industrial Research (CSIR) has to improve and invest on its human resources, physical infrastructure and communication and information systems, especially in its decentralized stations. It has to work on increasing research productivity (both technology and publication) and has to work more on increasing the level and quality of linkages and research collaboration. CSIR has to find a way to retain existing staff at the same time able to hire young staff, which will involve lifting the recruitment squeeze. There is also a need to look at better incentive system and higher compensation, especially in research institutes wherein staff turnover is a major problem and staff move to higher education institutes due to better compensation and opportunities for staff development. All these actions require substantial investment needed from government and partners. While Ghana is almost to reach the target of 6 percent budget allocation to agriculture, Ghana's investment is very low in relation to the size and importance of its agricultural sector (less than 2 percent compared to about 5 percent in Nigeria and 8-10 percent in agriculture-based Asian countries).

For both countries, it seems that leadership style and characteristics of the organization head are associated with organizational culture type and organizational management systems, and indirectly research productivity. Attention must be paid to improve leadership and organizational skills of the

existing managers and directors of research organizations. The gender of the organization head and of the researcher are significant in most models. Further study is needed to understand why female researchers and researchers in organizations with female heads have lower indicators of organizational performance and individual research output. It might be that the gender effects in variations in productivity are due to gender differentials in access to opportunities and resources for research, collaboration, or dissemination.

5. Concluding Remarks

Most studies on individual research productivity focus on individual characteristics, and this paper is among the first set of papers that models systematic variation in individual research productivity across organizations. Results of this study show that organizational characteristics matter in explaining variations in individual research productivity (measures in terms of quantity and quality of publications and technologies produced). Results of this study reinforces that improving organizational effectiveness can contribute to increased productivity of individual researchers. There are differences in the statistical significance and direction of correlation of various organizational-level factors between Nigeria and Ghana. This signifies local context matters and that various interventions need to be tailored to the specific context and constraints facing organizations and countries. In Ghana, human resources seem to be the more pressing constraint; while in Nigeria, organizational M&E systems and organizational plans and policies seem to be the more pressing constraints. What is consistent between Nigeria and Ghana is the significance of organizational leader's characteristics in explaining the presence and adequacy of organizational management practices and type of organization culture in various organizations. This in turn implies that attention must be paid to improve leadership and organizational skills of the existing managers and directors of research organizations.

While this paper provides useful insights and policy implications, it is constrained by several limitations of data. First, the dataset used in this study include small number of observations per organization (3 to 15 researchers per organization) although they were selected randomly and experts' opinion suggests that the sample is representative. Any discrepancy of the sample and the observed characteristics of a larger sample dataset (i.e., ASTI's dataset of researchers and researcher organizations in 2009) were adjusted using sampling weights in the modeling.

Second, measures of research output are based on self-reported values. Anonymity of the responses was important to the research design due to the possible sensitivities of the responses in perceptions. Moreover, locally-produced journals and publications in Nigeria and Ghana and in other developing countries are often not comprehensively available in international databases and search engines. For these reasons, this paper used self-reporting rather than bibliometrics data. To minimize the bias in self-reporting, the questionnaires were kept anonymous and confidential, which was emphasized to the respondents. It was emphasized by the organization heads and interviewers to answer the questions as honest and accurately as possible to help analyze important factors on how productivity and performance can be improved. In most cases, CVs were requested to be printed, so that respondents will find it easier in answering the questionnaires and minimize errors in self-reporting. It was also emphasized that the survey will help in identifying areas of capacity strengthening.

Third, variables on quality of publications and technologies produced have been included, but alternative measures can be explored. While this study measures presence of external collaborator, extent of dissemination, and extent of knowledge and awareness of adoption levels, it does not include measures of impact of these publications due to the inherent difficulty of measuring research. While this study is innovative in including a measure of perceived adoption levels of technologies produced, it does not include a more objective and actual adoption rates of these technologies.

As a future research agenda, better methods of collecting information as well as better indicators of adoption and impact of publications and technologies can be explored. A future line of inquiry will be to build up indicators of individual productivity of scientists and explore the relationship between individual and organizational productivity. It will also be useful to investigate further why female researchers appear to be more productive in Ghana and less productive in Nigeria than male researchers. The gender of the organization head is also statistically significant in explaining the presence of organizational management practices and organizational culture type across organizations. It might be that the gender effects in variations of productivity are due to gender differentials in access to opportunities and resources for research, collaboration, or dissemination. Lastly, cross-sectoral or cross-national comparison can be explored to determine whether institutional or national context matter in explaining scientists' productivity.

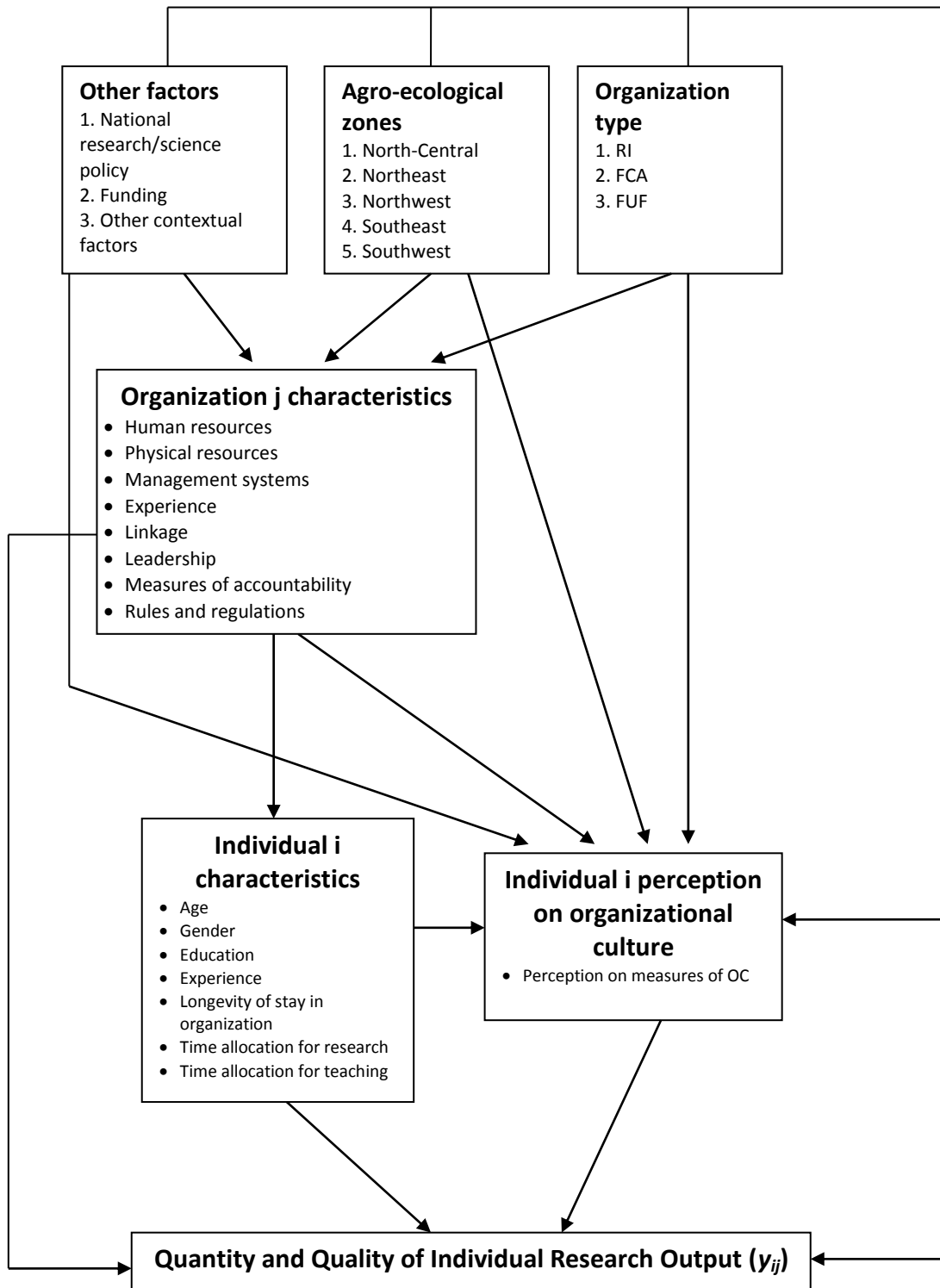
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Figure 1. Framework for Modeling Individual and Organizational Characteristics.



Source: Authors.

Table 1. Distribution and descriptive statistics of agricultural researcher's output, Nigeria and Ghana, 2010.

Count	Number of technologies produced (last 5 years) ¹ (%)		Number of publications produced (last 3 years) ² (%)	
	<i>Nigeria</i>	<i>Ghana</i>	<i>Nigeria</i>	<i>Ghana</i>
0	<i>75</i>	39	<i>19</i>	29
1	<i>10</i>	18	<i>6</i>	17
2	<i>6</i>	14	<i>8</i>	14
3	<i>2</i>	8	<i>5</i>	5
4	<i>2</i>	6	<i>5</i>	5
5	<i>2</i>	3	<i>7</i>	6
6	<i>1</i>	3	<i>5</i>	5
7	<i>0</i>	2	<i>5</i>	4
8	<i>1</i>	1	<i>7</i>	3
9	<i>0</i>	1	<i>4</i>	2
10	<i>0</i>	1	<i>4</i>	1
11-20	<i>1</i>	4	<i>15</i>	6
21-30	<i>0</i>	1	<i>5</i>	1
31-40	<i>0</i>	0	<i>3</i>	0
41-50	<i>0</i>	0	<i>2</i>	0
51-60	<i>0</i>	0	<i>1</i>	0
Mean	<i>0.76</i>	2.27	<i>8.28</i>	3.63
Std. Dev.	<i>2.22</i>	3.51	<i>10.09</i>	5.43
Variance	<i>5.10</i>	12.31	<i>104.10</i>	29.51
F-statistics from ANOVA (between organizations)	<i>2.30***</i>	1.26	<i>2.11***</i>	2.30***
F-statistics from ANOVA (between org. types)	<i>1.06</i>	2.24*	<i>11.00***</i>	1.71

Note: *Significant at 0.10 level; ** Significant at 0.05 level; *** Significant at 0.01 level. ¹Involve all technologies that the respondent helped developed including biological, chemical and mechanical technologies and management practices. ²Involve articles in international and national scientific journals, books, and book chapters published as first author or co-author. Source: IFPRI-ARCN survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011).

Table 2. Distribution and descriptive statistics of measures of the quality publications produced, Nigeria and Ghana, 2010.

Indicators	Nigeria	Ghana
Measures of quality of technologies produced		
Percentage of respondents with at least 1 international collaborator in developing technology	29*	32
Percentage of respondents with at least 1 national collaborator in developing technology	51	39
Percentage of respondents who are aware of information or evaluation of adoption or use of technology produced	38	20
Percentage of respondents who are aware of adoption level of technologies produced based on reported adoption level of technologies produced in areas where it was disseminated and demonstrated		
o no adoption (0 adoption)	53**	0
o limited adoption (20% or less)	24	9
o some adoption (21-40%)	0	4
o moderate adoption (41-60%)	13	26
o wide adoption (> 60%)	10	61
Measures of quality of publications produced		
Percentage of respondents with at least 1 international collaborator in producing publication	37	49
Percentage of respondents with at least 1 national collaborator in producing publication	78	77
Percentage of respondents based on the number of dissemination events for publications produced in last 4 years		
0	24	38
1	24	20
2	0	11
3	9	12
4	9	5
5	6	4
6	5	2
7	1	1
8	2	1
9	4	1
10	1	2
11-20	12	3
21-30	1	0
31-40	0	1
41-50	1	0
51-60	1	0

Note: *Percentage to total respondents who reported at least 1 technology or at least 1 publications produced; **Percentage to total respondents who reported being aware of information or evaluation on adoption or use of technology produced. Source: IFPRI-ARC survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011).

Table 3. Descriptive statistics of individual characteristics of sample agricultural researchers, Nigeria and Ghana, 2010.

Variable	Nigeria		Ghana
Dummy for gender (1=FEMALE)	0.31 (0.46)	^{/a}	0.20 (0.40)
AGE	3.60 (0.94)	^{/a}	3.93 (0.91)
≤ 20	3	^{/b}	0
21-30	5		6
31-40	38		27
41-50	37		35
≥ 51	17		32
Highest level of education (EDUC)	3.77 (1.33)		4.05 (1.07)
BSc	11		5
MSc	40		55
PhD	49		40
Number of years after last degree (POSTDEGREE)	4.94 (1.63)		3.86 (2.17)
< 1 year	6		9
1-4 years	34		23
5-7 years	22		24
8-10 years	12		10
> 10 years	26		34
Number of years in the organization (EXPORG)	4.90 (1.29)		5.20 (2.76)
< 1 year	5		7
1-4 years	10		17
5-7 years	18		11
8-10 years	22		9
> 10 years	45		55
Percentage of time allocated to research (RESEARCH)	39.76 (21.80)	^{/a}	53.17 (23.61)
Percentage of time allocated to teaching (TEACH)	34.12 (24.30)	^{/a}	19.51 (23.71)

Source: IFPRI-ARCN survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011). Note: ^{/a} Figures represent the mean and the ones in parentheses are the standard deviation. ^{/b} Percentage to total respondents per category; *Significant at 0.10 level; ** Significant at 0.05 level; *** Significant at 0.01 level.

Table 4. Descriptive statistics of characteristics of sample agricultural research organizations, Nigeria and Ghana, 2010.

Categories	Variable Name	Nigeria		Ghana	
		Ave.	SD	Ave.	SD
Human resources					
Total number of research staff	FTETOTAL	32.28	29.45	26.23	21.07
Total number of staff with PhD	FTEPHD	11.84	9.07	8.78	7.44
Total number of staff with MS	FTEMS	12.03	13.15	11.76	9.91
Total number of staff with BS	FTEBS	8.38	14.12	5.69	6.78
Satisfaction ¹ with human resources (1-5 scale)	HUMAN	2.81	0.97	2.60	0.95
Physical resources					
Satisfaction ¹ with the adequacy of laboratory facilities (1-5 scale)	LAB	2.3	1.08	2.18	1.00
Satisfaction ¹ with the adequacy of ICT (1-5 scale)	COM	2.28	0.99	2.01	1.00
Satisfaction ¹ with the adequacy of computers (1-5 scale)	COMPUTER	1.7	0.69	2.12	1.09
Management systems					
With M&E plan (1=dummy)	MEPLAN	0.62	0.49	0.62	0.5
With strategic plan (dummy)	STRAPLAN	0.62	0.49	0.81	0.4
With training plan (dummy)	TRAINPLAN	0.7	0.46	0.81	0.4
Satisfaction ¹ with M&E plan (1-5 scale)	MESATIS	1.98	1.84	3.54	0.52
Satisfaction ¹ with the strategic plan (1-5 scale)	STRASATIS	1.85	1.77	3.5	0.88
Satisfaction ¹ with training plan (1-5 scale)	TRAINSATIS	2.62	1.88	3.31	1.25
Experience					
Number of years since establishment	YEARESTAB	42	20	44	17
Leadership					
Gender of head (1=female)	LFEMALE	0.09	0.28	0	
Dummy for central goal of organization ¹ (1=research; 0=otherwise)	GOAL1	0.19	0.4	0.31	0.48
(1=to help farmers or solve poverty; 0=otherwise)	GOAL2	0.21	0.41	0.31	0.48
(1=teaching; 0=otherwise)	GOAL3	0.60	0.5	0.38	0.5
Graduate program of head	HEDUC				
Full program abroad				75	(percentage)
Sandwich program (abroad and local)				25	(percentage)
Number of years as head	HEXP				
< 1 year				19	(percentage)
1-3 years				50	(percentage)
4-5 years				33	(percentage)
Linkages					
With international linkages (dummy)	LINTL	0.32	0.47	0.75	0.44
With linkages with training institute (dummy)	LLTRAIN	0.38	0.49	0.38	0.5
With linkages with research institute (dummy)	LRES	0.66	0.48	0.75	0.44
With linkages with universities or colleges (dummy)	LEDUC	0.40	0.50	0.88	0.34
With linkages with private sector (dummy)	LPRIV	0.17	0.38	0.5	0.52
Average rating on organizational management practices					
Perception on organizational management practices	OMC	2.2	0.45	2.08	0.33
Dominant organizational cultural types					
Flexibility-dominant type	FLEX			69	(percentage)
Control-dominant type	CONTROL			31	(percentage)
Score on organizational cultural type					
Score on group cultural type				19.56	6.27
Score on development cultural type				24.88	6.34
Score on hierarchical cultural type				31.88	8.89
Score on rational cultural type				23.88	5.71

Note: ¹ As perceived by the head or representative of the organization interviewed; with scale 1 (not satisfied) to 5 (very satisfied). Source: IFPRI-ARCN survey (May-July 2010) and IFPRI-STEPRI survey (May-July 2011).

Table 5. Results of different models explaining the number of publications and technologies produced by individual researchers, Nigeria and Ghana, 2010.

Variables	Publication						Technology					
	Nigeria			Ghana			Nigeria			Ghana		
	Coef. ^{/a}	Std. Err. ^{/b}		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
<i>Individual Characteristics (fixed effects)</i>												
AGE	0.41	0.14	***	1.18	0.45	**	1.29	0.68	*	0.98	0.51	*
AGESQUARE	-0.08	0.02	***	-0.15	0.06	**	-0.14	0.09		-0.12	0.06	*
EDUC	0.42	0.03	***	0.40	0.05	***	0.38	0.09	***	0.45	0.06	***
POSTDEGREE	-0.01	0.07		0.25	0.08	***	0.05	0.23		0.31	0.10	***
POSTSQUARE	0.01	0.01		-0.02	0.01	***	0.00	0.02		-0.03	0.01	***
EXPORG	0.08	0.02	***	0.09	0.02	***	-0.09	0.10		0.06	0.03	**
FEMALE	-0.35	0.05	***	0.08	0.09		-0.09	0.17		0.05	0.11	
RESEARCH	0.01	0.00	***	0.00	0.00		0.01	0.00	**	0.00	0.00	
Constant	-0.84	0.33	**	-4.05	0.91	***	-5.56	1.40	***	-4.14	1.04	***
<i>Random effects</i>												
Intercept	0.46	0.06	***	0.63	0.13	***	1.31	0.23	***	0.50	0.11	***
<i>Log likelihood</i>	-1541.87			-407.96			-574.81					

Note: ^{/a} Reported values are the coefficients and not the marginal effects. ^{/b} Figures are the coefficients and the ones in parentheses are the standard errors.
 *Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level.

Table 6. Results of different models explaining the number of publications and technologies produced, with organizational-level factors, Nigeria and Ghana, 2010.

Variables	Publication						Technology										
	Nigeria			Ghana			Nigeria				Ghana						
	Poisson			Poisson			Logit		Poisson		Logit		Poisson				
	Coef. ^{/a}	Std. Err. ^{/b}		Coef.	Std. Err.		Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.			
<i>Individual characteristics (fixed effects)</i>																	
AGE	0.51	0.15	***	0.75	0.50		-1.33	1.31		0.09	0.58		-1.85	1.90	0.44	0.64	
AGESQUARE	-0.10	0.02	***	-0.08	0.06		0.16	0.18		0.01	0.08		0.22	0.25	-0.05	0.08	
EDUC	0.42	0.03	***	0.31	0.05	***	0.13	0.22		0.33	0.11	***	-0.56	0.19	0.20	0.07	***
POSTDEGREE	0.00	0.08		0.24	0.08	***	0.14	0.55		-0.07	0.24		-0.14	0.42	0.27	0.12	**
POSTSQUARE	0.01	0.01		-0.02	0.01	***	-0.01	0.06		0.00	0.03		0.03	0.04	-0.03	0.01	**
EXPORG	0.06	0.03	**	0.10	0.02	***	-0.83	0.27	***	-0.52	0.12	***	-0.02	0.12	0.08	0.04	**
FEMALE	-0.32	0.05	***	0.22	0.10	**	-0.09	0.42		-0.37	0.22	*	-0.17	0.49	0.20	0.12	
RESEARCH	0.01	0.00	***	0.00	0.00		-0.01	0.01		0.01	0.00	***	-0.02	0.01	-0.01	0.00	***
<i>Organizational characteristics (fixed effects)</i>																	
HUMINDEXHAT	0.01	0.14		1.08	0.51	**	-0.48	0.20	**	0.00	0.11		-0.93	0.81	0.10	0.26	
COMINDEXHAT	-0.11	0.14		0.15	0.56		-0.40	0.24	*	-0.30	0.09	***	0.18	0.89	0.43	0.26	*
PHYINDEXHAT	-0.04	0.13		-0.14	0.39		0.42	0.21	**	0.42	0.09	***	-0.06	0.62	-0.15	0.19	
PLANINDEXHAT	0.26	0.13	*	-0.31	0.27		0.74	0.25	***	0.35	0.12	***	-0.63	0.46	0.00	0.15	
LINKINDEXHAT	-0.08	0.13		0.05	0.39		-0.35	0.23		-0.55	0.09	***	0.38	0.55	0.07	0.17	
OCINDEXHAT	0.09	0.22		-0.13	0.05	**	-0.22	0.41		-0.99	0.25	***	0.05	0.21	-0.13	0.06	**
RESINSTITUTE	1.17	0.20	***	0.28	0.40		-0.70	0.62		0.88	0.32	***	0.60	0.81	0.28	0.24	
CONTROLHAT				-0.13	0.06	**							0.09	0.10	-0.03	0.03	
Constant	-1.20	0.55	**	0.93	2.69		7.61	2.87	***	-0.07	1.56		3.16	5.49	-0.09	1.83	
<i>Random effect</i>																	
Intercept	0.79	0.12	***	0.45	0.10	***				0.90	0.19	***			0.31	0.10	
<i>Log likelihood</i>	-1495.34			-573.73			-301.15				-404.62						

Note: ^{/a} Reported values are the coefficients and not the marginal effects. ^{/b} Figures are the coefficients and the ones in parentheses are the standard errors.

*Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level.

Table 7. Results of different models explaining the extent of external collaboration and dissemination of publications produced, Nigeria and Ghana, 2010.

Variables	National research collaboration				International research collaboration				Number of dissemination events							
	Nigeria		Ghana		Nigeria		Ghana		Nigeria		Ghana					
	Coef. ^a	Std. Err. ^b	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.				
<i>Individual characteristics</i>																
AGE	2.01	1.44	1.60	2.44	2.40	1.72	-1.70	2.06	0.25	0.19	1.58	0.70	**			
AGESQUARE	-0.25	0.19	-0.11	0.32	-0.28	0.22	0.19	0.27	-0.04	0.03	-0.21	0.09	**			
EDUC	-0.38	0.16	**	-0.43	0.30	0.36	0.18	**	0.42	0.23	*	0.22	0.04	***		
POSTDEGREE	-0.86	0.41	**	-0.16	0.47	-0.20	0.47	0.40	0.42	-0.32	0.10	***	0.30	0.13	**	
POSTSQUARE	0.10	0.04	**	-0.01	0.05	0.03	0.05	-0.06	0.04	0.04	0.01	***	-0.02	0.01	**	
EXPORG	0.24	0.17		-0.04	0.14	-0.03	0.17	0.21	0.12	*	0.06	0.04	0.10	0.03	***	
FEMALE	0.23	0.32		0.08	0.55	0.01	0.35	0.43	0.50	-0.06	0.08		-0.37	0.15	**	
RESEARCH	0.00	0.01		-0.03	0.02	*	0.01	0.01	-0.02	0.02	-0.01	0.00	***	0.02	0.00	***
<i>Organizational characteristics (fixed effects)</i>																
HUMINDEXHAT	-0.14	0.15		-2.16	1.37		-0.04	0.17	0.13	1.13	0.12	0.10	0.10	0.31		
COMINDEXHAT	0.05	0.17		2.00	1.19	*	0.29	0.19	1.50	1.09	-0.04	0.11	-0.31	0.30		
PHYINDEXHAT	0.04	0.16		-1.15	0.95		-0.12	0.18	-0.43	0.82	-0.01	0.10	0.91	0.24	***	
PLANINDEXHAT	-0.05	0.16		0.32	0.67		0.20	0.18	-0.67	0.58	-0.08	0.10	-0.10	0.15		
LINKINDEXHAT	0.02	0.15		-0.96	0.73		-0.08	0.17	-0.68	0.74	-0.14	0.09	0.32	0.19	*	
OCINDEXHAT	-0.12	0.34		0.31	0.23		-0.10	0.36	-0.33	0.23	0.47	0.17	***	-0.09	0.07	
RESINSTITUTE	-0.43	0.46		1.83	1.15		-0.12	0.46	0.58	0.96	0.95	0.21	***	-1.98	0.30	***
CONTROLHAT				0.15	0.14				-0.02	0.14				0.04	0.03	
Constant	-2.47	2.70		-2.01	7.27		-7.32	3.40	**	1.33	6.60	-0.04	0.54	-5.65	1.81	***
<i>Random effect</i>																
Intercept	0.00	0.39		0.00	0.38		0.00	0.31	0.52	0.31	0.54	0.10	0.00	0.08		
Log Likelihood	-152.58		-67.65		-139.42		-85.16		-1097.40		350.72					

Note: ^a Reported values are the coefficients and not the marginal effects. ^b Figures are the coefficients and the ones in parentheses are the standard errors.
 *Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level.

Table 8. Results of different models explaining the extent of external collaboration and knowledge of adoption of technologies produced, Nigeria and Ghana, 2010.

Variables	International technology collaboration				National technology collaboration				Knowledge of adoption or evaluation			
	Nigeria		Ghana		Nigeria		Ghana		Nigeria		Ghana	
	Coef. ^{/a}	Std. Err. ^{/b}	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
<i>Individual characteristics</i>												
AGE	-2.15	2.97	-0.71	2.35	-0.78	1.87	2.45	2.48	1.16	2.17	3.82	3.90
AGESQUARE	0.27	0.42	0.02	0.31	0.08	0.25	-0.31	0.32	-0.06	0.30	-0.47	0.50
EDUC	1.57	0.94 *	0.36	0.28	0.10	0.32	0.07	0.25	-1.06	0.40	-0.22	0.40
POSTDEGREE	4.00	3.11	0.78	0.55	-0.45	0.79	0.40	0.47	1.02	0.85	-0.18	0.81
POSTSQUARE	-0.44	0.33	-0.03	0.05	0.04	0.09	-0.03	0.05	-0.12	0.09	0.02	0.09
EXPORG	0.76	1.10	0.17	0.15	0.39	0.42	0.00	0.14	0.85	0.46 *	0.37	0.25
FEMALE	2.83	1.89	0.22	0.60	-0.11	0.59	0.59	0.56	0.00	0.70	-0.19	0.81
RESEARCH	-0.02	0.03	0.04	0.02 **	-0.01	0.01	0.01	0.02	0.00	0.02	0.02	0.03
<i>Organizational factors (fixed effects)</i>												
HUMINDEXHAT	-0.09	0.86	0.41	1.45	-0.25	0.33	-0.99	1.39	0.02	0.41	-6.97	104.75
COMINDEXHAT	-0.41	0.81	-2.55	1.11 **	-0.01	0.32	-2.57	1.20 **	0.00	0.40	12.86	109.86
PHYINDEXHAT	0.32	0.74	1.84	0.83 **	0.44	0.28	0.55	0.94	0.35	0.33	4.91	24.02
PLANINDEXHAT	0.41	0.88	0.39	0.64	0.23	0.31	0.36	0.72	0.11	0.37	7.43	18.15
LINKINDEXHAT	-0.49	0.89	1.38	0.81 *	-0.16	0.31	1.49	0.86 *	-0.62	0.39	12.69	102.36
OCINDEXHAT	-3.53	2.54	0.13	0.27	-0.92	0.66	0.15	0.25	-0.63	0.76	-0.73	0.43 *
RESINSTITUTE	3.47	2.59	-0.19	1.02	-0.36	0.82	0.90	1.07	2.04	1.01 **	10.09	107.67
CONTROLHAT			-0.22	0.16			-0.08	0.17			-0.09	0.69
Constant	-20.00	12.53	6.02	7.45	0.87	4.71	-0.67	8.00	-7.00	5.49	-1.00	203.97
<i>Random effect</i>												
Intercept	2.16	1.60	0.18	0.96	0.00	2.32	0.57	0.39	0.41	1.26	0.00	0.32
Log Likelihood	-29.74		-57.71		-50.78		-69.91		-42.65		-33.48	

Note: ^{/a} Reported values are the coefficients and not the marginal effects. ^{/b} Figures are the coefficients and the ones in parentheses are the standard errors.

*Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.01 level.